Recovery of seabird colonies on Rat Island (Houtman Abrolhos) following the eradication of introduced predators

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The large seabird colonies on Rat Island in the Houtman Abrolhos group were extirpated by the combined impacts of introduced *Rattus rattus* (black rat) and *Felis catus* (cat) as well as guano mining by the 1930s. Both introduced predators were eradicated following a baiting program conducted in 1991, with the last cat dying around 2000. The Rat Island Recovery Project was established to monitor the return of breeding seabirds after an absence of approximately 60 years. The seabird colonies began to re-establish within a decade of the eradication program and the number of species and breeding pairs on Rat Island increased dramatically in 2011 and 2012. The recovery of the seabird colonies presents a number of management issues on an island where human uses have developed in their absence. Management decisions will also need to be made about whether to enhance the recovery of important natural processes by facilitating the restoration of some of the conservation values lost from the terrestrial ecosystem on Rat Island.

KEYWORDS: eradication, introduced predators, islands, recovery, restoration, seabird colonies

INTRODUCTION

The eradication of introduced predators from islands is now a widely practiced conservation measure (Veitch *et al.* 2011; Dunlevy *et al.* 2011). However, the long time intervals between treatment and response have made it difficult for managers to find resources to monitor and record subsequent ecological trajectories or apply adaptive management approaches to enhancing restoration outcomes.

The eradication of black rats and feral cats from Rat Island in Western Australia is predicted to be the initial critical intervention in the recovery of the terrestrial ecosystem by providing for the return of breeding seabirds and the associated marine nutrient subsidy (Smith *et al.* 2011). The marine nutrient and energy resources, transferred by seabirds from sea to land, are expected to drive the partial recovery of the terrestrial ecosystem by rebuilding soil organic matter, increasing primary productivity and providing for scavengers (Mulder *et al.* 2011). Changes in the flora might also be predicted with the increased nutrient availability favouring faster-growing species including regional nitrophilous and ornithocoprophilic plants. Invertebrate and reptile populations are likely to increase in abundance in response to the increased primary productivity, and more species from the regional pool of volant insects and birds may be able to colonise and increase the islands biodiversity (Mulder *et al.* 2011).

RAT ISLAND

Rat Island is an elevated (3–4 m above MSL) relatively flat island in the Easter Group of the Houtman Abrolhos archipelago 78 km west of Geraldton, Western Australia (Figure 1). The island is broadly rectangular in shape with its long axis oriented north–south, and is comprised of coralline limestone (Wallabi Limestone) formed during the highstand of the Eemian stage 125 000 years BP (Collins *et al.* 1997). It has a supratidal area of 61 ha and is sparsely vegetated (Harvey *et. al.* 2001). The area would have been a low coastal ridge during the latter part of the Pleistocene and then isolated from the mainland by the most recent marine transgression about 7000 years ago. Colonisation by seabirds and the accumulation of its historical mantle of guano would have occurred during the later Holocene period.

The Abrolhos archipelago is perched on the edge of the continental shelf, adjacent to the southward-flowing Leeuwin Current, and consequently provides important breeding sites for seabirds, particularly tropical species (Storr *et al.* 1986; Gaughan *et al.* 2002).

Guano mining began in earnest on Rat Island in 1885 and wound up in 1915 (Stanbury1993; Burbidge *et al.* 1996). The predominately Chinese mine workers dug and swept up the guano-enriched soil, levering out the surface limestone in order to get access to the material sequestered in fissures and cracks. Low embankments were constructed for trolley lines that carried the excavated material back to the shipping stockpiles at the northeastern end of the Island. The product was then loaded onto vessels via trolley lines that ran out onto a stone jetty.

The habitat available to nesting seabirds was drastically altered during this time. The soil was almost completely removed from about 81% of the island's surface, leaving limestone pavement, sink holes, rock-piles of coralline slabs, piles of smaller diameter screened rock material, a system of anastomosing low embankments and little perennial woody vegetation (Dunlop & Rippey 2004).

The eastern edge of Rat Island provides sheltered access to deep water and has provided suitable sites for

Figure 1. Location map of Rat Island in the Easter Group of the Houtman Abrolhos Islands off Geraldton in southwestern Australia.

fishing camps since at least the 1940s. Since World War II professional *Panulirus cygnus* (western rock lobster) fishers have occupied these camps. There have been up to 59 rock lobster camps on Rat Island (currently over 70 shacks) and one camp associated with the operations of a cultured-pearl lease. The foundations of a number of abandoned camps occur to the south of the current settled area. The settlement footprint of Rat Island, including an airstrip and access pathways, is ~14 ha or 22.9% of the total area (Rat Island Recovery Project, unpubl. data). However, much of this area was formerly mined for guano and would have little additional impact on the island's biodiversity.

In 2004 the Rat Island Recovery Project was established and began with a feasibility study published in January of that year and provided to the Department of Fisheries (Dunlop & Rippey 2004). Since 2008 the project has sought to monitor and document the recovery of the Rat Island seabird colonies and the terrestrial ecosystem following the successful eradication of black rats and feral cats in the 1990s and to facilitate restoration projects that may enhance the recovery process. The timing of the Rat Island Recovery Project (2003–2013) has provided a unique opportunity to investigate and document seabird responses to a successful introduced predator eradication program conducted during the 1990s. This paper documents the early trends in the recovery of Rat Island's seabird colonies. The next phase in the Rat Island Recovery Project will focus on the recovery of the island's terrestrial ecosystem following seabird recolonisation.

History of seabird colonies

Rat Island was surveyed and named by Lieutenant John Lort Stokes on the HMS *Beagle* in April 1840. Evidently the island was already populated with black rats to the extent that they gave its name: *'The centre island we named Rat Island, from the quantity of that vermin with which it was infested.'* (Stokes 1846 p. 145).

The presence of black rats prior to any European inhabitation of the Abrolhos is puzzling but was presumably the result of some undocumented visit by a sailing ship or of a shipwreck. Stokes visited in April (Stokes 1846), a period outside the spring–summer breeding period of the large colonies of tropical terns on Rat Island. These colonies were documented later in the colonial period.

Rat Island was the scene of what has become arguably the best-documented ecological calamity in the history of European settlement in Western Australia. Archibald James Campbell estimated in 1889 that the mixed colony of *Anous stolidus* (common noddy) and *Sterna fuscata* (sooty tern) held 1 452 000 birds (Serventy *et al.* 1971). These colonies were completely extirpated by the late 1930s through the combined effects of guano mining, the introduction of cats, and egg collecting by fishermen (Burbidge *et al.* 1996).

During the colonial period the Rat Island tern colonies were at least three times the size of the spectacular breeding aggregations that still occur on the southern end of Pelsaert Island (Burbidge *et al.* 1996) in the Southern Group. Gibson (1908) visited both islands and noted that the sooty tern colony on Rat Island was much larger than the one on Pelsaert. His observations effectively confirm that the colonies on Pelsaert Island today are not the result of displacement from the Rat Island population.

As well as the spectacular tern colonies, Rat Island had thousands of *Puffinus pacificus* (wedge-tailed shearwater) burrows in its guano mantle and low sand dunes until at least 1913 (Stanbury 1993; Alexander 1922). Other Abrolhos seabird species may also have nested on Rat Island at the time, particularly those (of larger size) that were least vulnerable to rat predation.

By the time the rock lobster fishing settlement became established at the Abrolhos in the 1950s Rat Island was a worked-out exhausted environment, now silent with the loss of its great tern and shearwater colonies. Many surface-nesting seabirds such as terns could potentially have utilised the mined-out landscape for breeding in the absence of the introduced predators. However, the thorough removal of the guano mantle and overlying low sand dunes effectively eliminated the nesting habitat for burrowing species (shearwaters and storm-petrels) over much of the surface.

Impact of introduced predators

Despite the presence of black rats, the constant disturbance of the guano diggers and dramatic changes in nesting habitat, the tern colonies on Rat Island were still reported to be 'prodigious' in November 1913 (Alexander 1922). Some egging by fishermen is thought to have occurred both during and after the guano mining years, but this was unlikely to have been beyond sustainable levels as the Sooty Tern is quite tolerant of egg harvesting (Ridley & Percy 1958). However cats, introduced by the guano miners between 1889 and 1913 (Alexander 1922) to control the rats, became established and predated nesting terns during the breeding season. Alexander (1922) predicted the extirpation of the common noddies in the Rat Island colony after observing the impact of cat predation during his visit in 1913.

A small and dwindling number of common noddies were still present on Rat Island in 1936 and sooty terns were still present in 1938, but both species were probably extirpated around that time (Burbidge *et al.* 1996). *Egernia stokesii stokesii* (spiny-tailed skink, a subspecies endemic to the Abrolhos Islands) occurred on Rat Island. It also appears to have been extirpated from Rat Island by the cats.

The process that occurred on Rat Island appears to be an example of 'hyperpredation' (Russell & Le Corre 2009; Russell 2011) caused by the interaction of two introduced predators, in this case the black rat and the cat. High concentrations of seabirds were persisting in the presence of the black rats until the introduction of cats by the guano miners. These seabirds (mainly sooty terns and common noddies) had a limited, highly synchronised breeding season and it is suggested that they were able to 'swamp' the rats with their enormous numbers over a short period of time. As indicated by Alexander (1922) the prey availability for cats outside this season was limited. This low food abundance on Rat Island during the autumn and winter may have reduced rat numbers to relatively low levels at the start of spring and the onset of seabird breeding. However, as with other examples of

hyperpredation (Russell 2011), cats could switch from seabird to rat and rabbit (also historically present on Rat Island) consumption in autumn and winter and consequently maintain their numbers between seabird breeding seasons. The depredations from the relatively high cat populations during the breeding seasons would then have been sufficient to drive rapid decline in the noddy and tern colonies on Rat Island. As the seabirds declined cat predation on the rats increased and both predator populations would probably have reduced to lower levels.

METHODS

Eradication of introduced predators

In 1991 Andrew Burbidge and Phil Fuller of the Department of Conservation and Land Management (Western Australia), Randall Owens from the Department of Fisheries (Western Australia) and Ken Johnson from the Conservation Commission (Northern Territory) undertook a program to eradicate black rats and cats from Rat Island. At the time there had been no confirmation of the presence of *Mus musculus* (house mouse). The objective of this intervention was primarily to prevent the black rat population on Rat Island and its satellites from becoming a platform for the invasion of other islands in the Easter Group and ultimately the rest of the Houtman Abrolhos, ie it was conceived as a biosecurity rather than an ecosystem recovery measure.

Rat Island and its near neighbours (Bushby, Little Rat, Roma, Little Roma and Dry) were baited with oats vacuum-impregnated with the anticoagulant rodenticide pindone. White Bank, just north of Rat Island, was inspected for rat sign, but no sign was found and it was not baited.

Baiting commenced on 30 November and was completed on 7 December 1991. About one cupful of bait was placed into thin plastic bags, which were placed on the ground, in a 50 m grid on the larger islands, and more densely spaced on smaller islands. Baits were inspected every three to four days and replaced if partially or completely consumed. All partly consumed bait bags were replaced with full bags at the end of the project and an additional bag of bait was placed in the centre of each 50 x 50 m grid at project completion.

Cat control using traps was conducted for several months after the rat baiting. No rats were observed after the baiting program was completed but one or two cats persisted for some years. The last surviving cat died in around 2000 (Russell Dyson pers. comm. 2003).

Seabird survey

The current investigation commenced with a field visit to Rat Island in December 2003. Observers made systematic day and night searches for breeding seabirds on each of the field surveys conducted in December 2003, December 2008, February 2012, August 2012, December 2012, February 2013 and April 2013. The number of breeding pairs was censused by locating and counting nest sites, counts of birds flying over colonies, or by mapping colony boundaries and transect-based density sampling. The size of the large sooty tern colony in December 2012 was estimated by mapping the colony boundaries using GIS techniques and then estimating nest densities with seven randomly located 50 x 2 m (100 m^2) belt transects. These transects were completed with head-torches at night when birds tended to remain incubating on the nest in the presence of the observers.

Adult and fledgling *Onychoprion anaethetus* (bridled terns) and sooty terns were individually marked with numbered alloy bands (supplied by the Australian Bird and Bat Banding Scheme) to enable future estimates of site and area fidelity in the adults and colony philopatry in the progeny reared on Rat Island.

RESULTS

Seabird recolonisation

RECORDS OF SEABIRD COLONIES PRIOR TO 2003

There were a number of records of incipient seabird recolonisation prior to that time. One pair of *Larus pacificus* (Pacific gull) was recorded breeding on Rat Island in 1996 and two pairs in 1999 (A A Burbidge pers. obs.). Twenty-one *Sternula nereis* (fairy tern) nests were counted on the beach at the northern end of Rat Island in November 1999 (A A Burbidge pers. obs.).

SEABIRD RECOLONISATION AFTER 2003

Surman & Nicholson (2009) reported six pairs of Pacific gulls and eight possible little shearwater burrows in December 2006 (outside the breeding season for the latter species). Our surveys in August suggested that not all of the Pacific gull pairs present in summer breed on Rat Island. We were also unable to confirm the presence of breeding *Puffinus assimilis* (little shearwater) during the breeding period (April and August).

About 300 pairs of fairy terns nested on Rat Island in November 2007 (R E Johnstone pers. comm. 2013).

The numbers of seabirds recorded breeding on Rat Island since 2003 are presented in Table 1. Since 2003 a considerable increase has been observed in both the number and diversity of seabirds nesting on the island.

Figure 2 represents the spatial extent of the colonies prior to 2012, and Figure 3 shows the colonies documented by the 2012–2013 breeding season. By 2012 (12 years after the demise of the last cat) eight seabird species had returned to breed on Rat Island. In 2012–2013 this involved an estimated 72 923 breeding pairs with the vast majority being sooty terns.

During December 2012 observers checked most of the other Easter Group islands known to have contained sooty tern colonies in recent years (Burbidge *et al.* 1996; C A Surman pers. comm. 2013: J N Dunlop pers. obs.: including Wooded, Morley, Leo, Campbell, Suomi, Keru, Serventy, Alexander and Gilbert Islands). All these islands were vacant suggesting that the entire Easter Group sooty tern breeding population had moved onto Rat Island in that year.

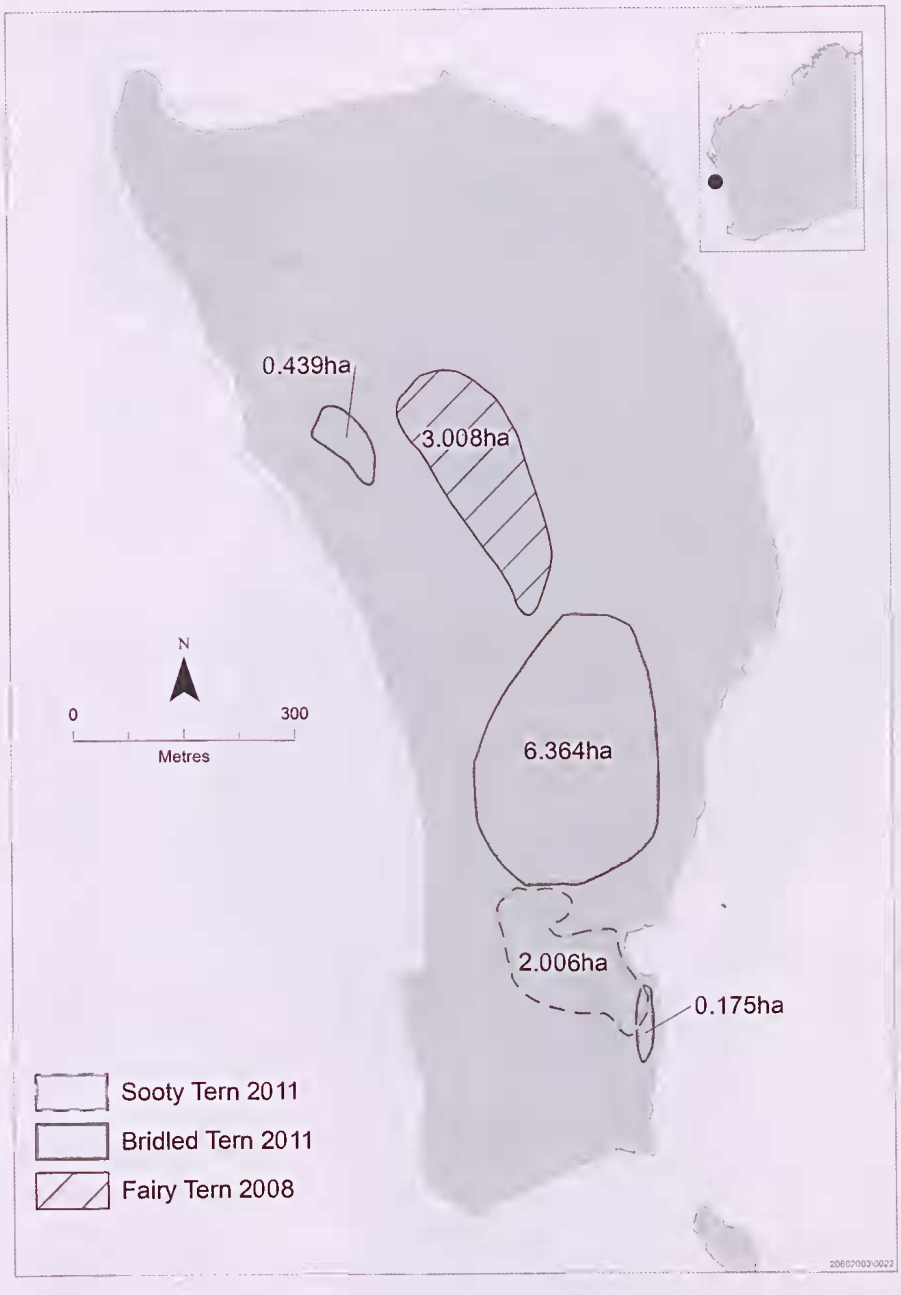

Figure 2. Seabird colonies up to the 2011–2012 season.

DISCUSSION

Seabird recolonisation trends

The earliest tentative indications of seabird recolonisation were observed in 1996, five years after rat eradication when there were one or two cats remaining on the island. Fairy terns (a species with little breeding site fidelity) established colonies in 1999, 2007 and 2008, with increasing colony size each year. Fairy terns naturally nest in the open on beaches, coral rubble or other reflective substrates with a preference for sites that provide nearby cover for chicks. The denuded, mined-out limestone surfaces (with nearby rock-piles) on Rat Island would appear to be ideal habitat for this species as a very large colony of 750 pairs was nesting there in December 2008 (Figure 2; Table 1).

When this project commenced in 2003 there were six breeding pairs of bridled terns nesting near the southern end of the Island (Figure 2; Table 1). By 2008 there were between 50 and 100 pairs breeding at the southern end of the Island most with nests under rock-piles left by the guano miners. The early occurrence of the bridled tern is significant. Firstly as the regional metapopulation of this species has been rapidly expanding in response to changes in ocean climate (Dunlop 2011; Dunlop & Surman 2012) potentially increasing the number of prospectors around Rat Island. Secondly bridled terns prefer to nest under cover (provided in this case by the mined rock-piles), have high nest-site fidelity (eg on Penguin Island: Dunlop & Rippey 2005) and are a common nesting associate with other dark terns, including sooty terns in the Abrolhos and at Lancelin Island (Dunlop & Rippey 2004) (Figure 1). As such, the consistent presence of breeding bridled terns on Rat Island from 2003 to 2011 may have facilitated sooty tern settlement by breaking down the 'information barrier' with respect to colony predator security (Dunlop 2009).

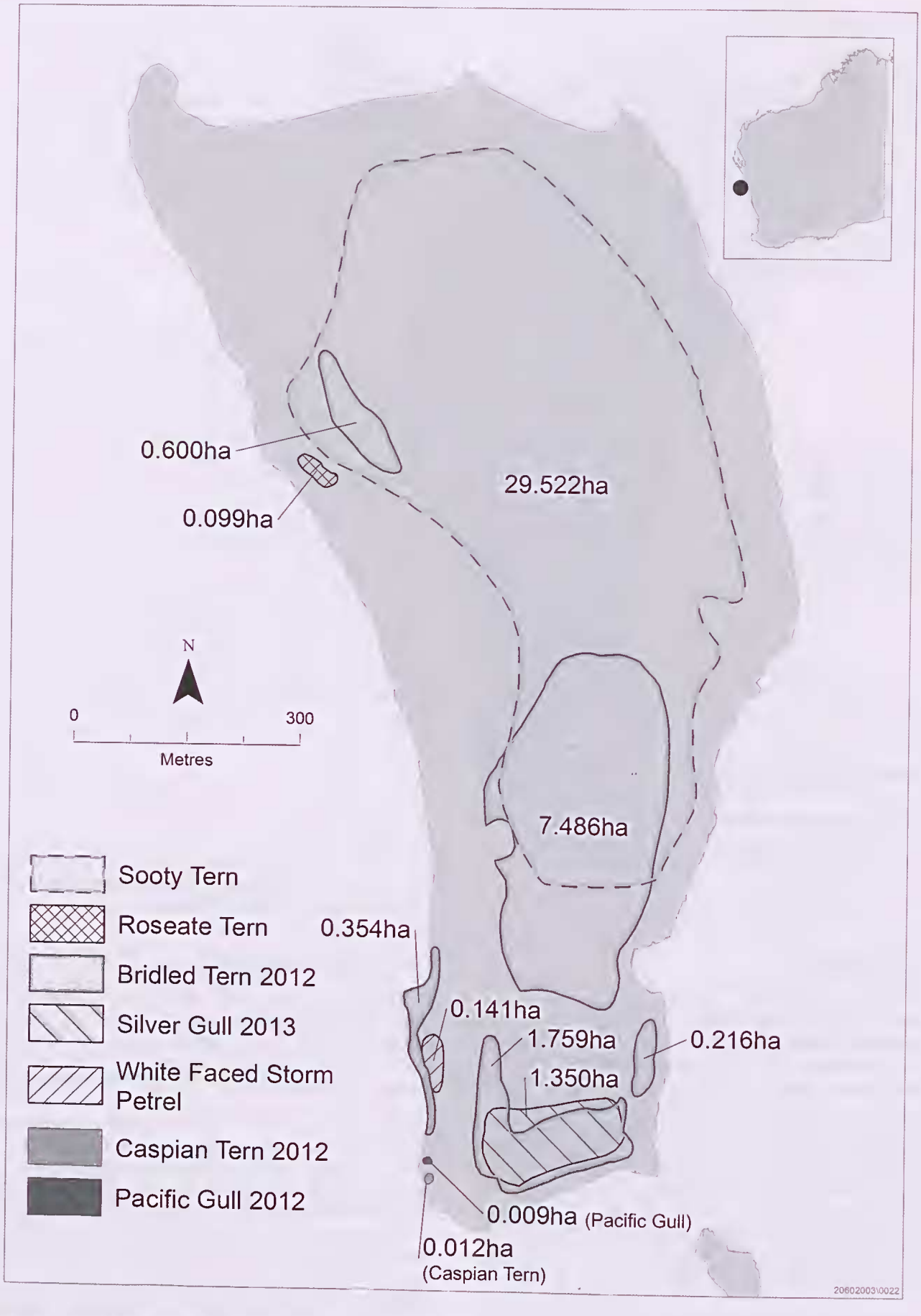

Figure 3. Seabird colonies in the 2012–2013 season.

Table 1. Rat Island Recovery Project records of breeding seabird numbers, colony areas and estimated colony densities on Rat Island from 2003 to 2013.

Seabird species	Date estimated	Area occupied (ha)	Estimated density (pairs/ha)	Colony size (pairs on Rat Island)
Bridled tern 2003	Dec 2003	–	–	6
Bridled tern 2008	Dec 2008	–	–	50–100
Bridled tern 2011	Feb 2012	6.9	25	174
Bridled tern 2012	Dec 2012	8.4	25	210
Fairy tern 2008	Dec 2008	3.0	–	750
Sooty tern 2011	Feb 2012	2.0	–	5000
Sooty tern 2012	Dec 2012	29.52	2400	72324
Roseate tern	Dec 2012	0.09	–	300
White-faced storm-petrel 2012	Aug 2012	0.14	51	27
Caspian tern 2012	Aug & Dec 2012	–	–	1
Pacific gull 2012	Dec 2012	–	–	1
Silver gull	Apr 2013	1.35	44	60

The initial sooty tern colony in 2010–2011 utilised remnant *Nitraria* and *Tecticornia* succulent heath at the southern island. This was expected as this is the breeding habitat utilised elsewhere in the Abrolhos (Serventy *et al.* 1971; Dunlop & Rippey 2004). However, the large colony in 2012 (Figure 3) utilised the guano-mined rock-pile habitats. Clearly in the absence of the introduced predators the existence of a novel habitat structure was not a significant barrier to sooty tern recolonisation.

The establishment of a colony of *Pelagodroma marina* (white-faced storm-petrel), sometime after 2008, was particularly remarkable as these small, burrow-nesting seabirds are particularly vulnerable to black rat and even house mouse predation and would not have been able to persist on Rat Island even prior to the introduction of the cats (Towns *et al.* 2011).

CONCLUSIONS

The monitoring of seabird responses to the eradication of introduced predators on Rat Island indicates that the initiation of seabird recolonisation can take place within a decade if there are drivers within regional metapopulations and a mechanism for overcoming the 'information barrier'. Similar rates of recovery have been recorded on other seabird Islands (Jones *et al.* 2011).

Even highly altered or novel habitats, such as mined-out guano fields, may be utilised by some surface-nesting seabird species in the absence of introduced predators. However, the recovery of seabird colonies after lengthy periods of absence may raise a range of management issues where various human uses and activities have become entrenched.

Terrestrial ecological recovery could, however, be limited or potentially derailed by some unremediated human-induced changes to Rat Island, including the removal of much of the soil by guano mining, introduced plants and animals, habitat degradation, human disturbance and the extent of the settlement footprint.

Future objectives for the management of Rat Island could settle for accommodating the changes now being driven by the resumption of natural processes (recovery) or they could specify further interventions towards ecological restoration (Clewell & Aronson 2013). That is, taking actions intended to return the biodiversity of Rat Island closer to its original undisturbed condition. These interventions might include the control of some potential ecological weeds, the eradication of the house mouse population, the restoration of some habitat areas with remnant soil for burrow-nesting seabird species and the reintroduction of the extirpated reptiles.

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